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B. T. GALLOWAY, *Chief of Bureau.*

THE TIMBER ROT CAUSED BY LENZITES SEPIARIA.

BY

PERLEY SPAULDING,

Pathologist, Investigations in Forest Pathology.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 21, 1911.

Sir: I have the honor to transmit herewith a paper entitled "The Timber Rot Caused by Lenzites Sepiaria," by Dr. Perley Spaulding, Pathologist in the Office of Investigations in Forest Pathology of this Bureau. I recommend that it be published as Bulletin No. 214 of the series of this Bureau.

This paper summarizes and brings up to date our knowledge concerning this serious wood-rotting fungus. It contains new information concerning its life history and gives practical methods of preventing its ravages. It is designed as a contribution toward our knowledge of the fundamental facts of forest pathology in this country. At the time the manuscript was first prepared there was no adequate publication upon this form of timber rot in any language; recently, however, such a paper, Falck's "Die Lenzitesfäule des Coniferenholzes," has been issued in Germany. So far as the two papers cover the same ground they agree in essentials, but vary in minor details. The fields and conditions are so different in the two countries that nothing else could be expected.

Dr. Spaulding is indebted to the custodians of the following herbaria for the privilege of collecting data from their collections: Missouri Botanical Garden, University of Wisconsin, New York Botanical Garden, New York State Museum, Harvard University, University of Vermont; also to Mr. E. T. Harper, for allowing similar work in his private herbarium.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE TIMBER ROT CAUSED BY LENZITES SEPIARIA.

INTRODUCTION.

The value of the total timber and wood cut in the year 1908[a] in the United States was slightly more than $1,000,000,000. About three-fourths of this immense production was supplied by the coniferous species of trees. A large proportion of the timber used in heavy construction, such as bridges, railroad ties, trestles, etc., is coniferous. One may obtain a slight idea of the enormous quantity of coniferous timber that is required from the fact that untreated coniferous railroad ties last only from 1 or 2 to 10 years, according to their conditions of use, the average length of service being about 7 years. Because of the great aggregate values involved, any factor which influences the length of service of this timber becomes a matter of primary importance. This is especially true at the present time when we are threatened with a shortage of timber of all kinds. The most important factors affecting the length of service of coniferous timber when exposed to the weather or in contact with the soil are the wood-rotting fungi. These greatly shorten the period of usefulness of such timber and thus help to increase the already too great demands upon our forests.

While there are dozens of wood-rotting fungi which attack coniferous wood, certain ones are especially prevalent and destructive in their action. *Lenzites sepiaria* (Wulf.) Fr. and *Lentinus lepideus* Fr. are probably the most widespread and injurious in this country. The former is most destructive in the southern part of the country, while the latter is very prevalent in the northern part, although both are widely distributed in both sections. *Lenzites sepiaria* is common wherever coniferous timber grows or is used. In the north the climatic conditions are such that peeled timber will season before the fungus can get well started in its growth, but it succeeds in causing the decay of unpeeled timber.

In spite of the economic importance of this fungus, not only in America but in Europe, no publication, so far as the writer knows,

[a] Bureau of the Census, Forest Products, vol. 10, p. 5, 1909.

adequately considers the decay caused by *Lenzites sepiaria.*[a] Practically all the literature concerning this species and the timber rot caused by it consists of short notes on occurrence and short paragraphs upon the damage caused.

ECONOMIC IMPORTANCE OF LENZITES SEPIARIA.

The damage inflicted in America alone by *Lenzites sepiaria* is enormous. This fungus, together with several others, destroys a large proportion of all untreated coniferous railroad ties and telegraph and telephone poles which are in service in the country. Probably one-fourth of this damage is done by *Lenzites sepiaria.*

The valuation of the railroad ties and telegraph and telephone poles furnished by the coniferous species of trees in 1908[b] was in round numbers $32,500,000. If the above estimate of damage done by *Lenzites sepiaria* is anywhere near correct, this would mean that timber worth about $8,000,000 annually has its length of service seriously shortened by this fungus. Under present methods of American railroading it is probable that an average length of service of an unrotted coniferous tie would scarcely be more than 12 to 15 years—that is, the tie will be worn out by the end of this period. The actual average service of untreated coniferous ties can hardly be placed at more than 5 to 8 years. Thus, we find the wood-rotting fungi practically diminishing the service of this timber by one-half. Moreover, there are vast quantities of timber in the form of piling, bridge timbers, trestles, sidewalks, fence posts, etc., which are also destroyed by this fungus.

DISTRIBUTION AND HOST WOODS OF LENZITES SEPIARIA.

[The location of certain cabinet specimens is indicated by arbitrary signs as follows: (*), In the herbarium of the Missouri Botanical Garden; (†), in the pathological collections of the Bureau of Plant Industry; (‡), in the herbarium of the New York Botanical Garden; (§), in the cryptogamic herbarium at Harvard University; (‖, with number), in the forest pathological field collection; (¶), in the private herbarium of E. T. Harper; (**), in the herbarium of the New York State Museum; (††), in the Frost Herbarium at the University of Vermont; (‡‡), in the herbarium of the University of Wisconsin.]

GEOGRAPHIC DISTRIBUTION.

THE FUNGUS IN FOREIGN COUNTRIES.

Lenzites sepiaria has been reported from and collected in the following countries:

EUROPE.

England: Berkeley (1836, 1860), Cooke (1871, 1883, 1888–1890), Smith (1891), Sowerby (1814), Stevenson (1886).
Norway: Blytt (1905), Fries (1849), Karsten (1882).

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[a] Since this manuscript was prepared the writer has first seen Falck's Die Lenzitesfäule des Coniferenholzes, issued as part 3 in Möller's Hausschwammforschungen, 1909.

[b] Bureau of the Census, Forest Products, vol. 10, pp. 66–67, 107, 1909.

Sweden: Fries (1849, 1863), Karsten (1882), Murrill (1904, 1908), Persoon (1799, 1801), Vleugel (1908), Wahlenberg (1820, 1826, 1833).

Russia: Lapland—Karsten (1876), Sommerfeldt (1826), Wahlenberg (1812). Finland—Karsten (1876, 1881, 1882, 1889, Fung. Fenn. No. 88), Thesleff (1894). Moscow—Bucholtz (1897). St. Petersburg—Perdrizet (1876).

Denmark: Fries (1849), Hornemann (1837), Rostrup (1902).

Germany: Bachmann (1886), Fuckel (1869), Hennings (1898, 1903), Hoffmann (1797–1811), Magnus (*), Pabst (1876), Rabenhorst (1840, 1844), Röhling (1813), Winter (1884). Baden—Jack, Leiner, and Stizenberger (Krypt. Badens, No. 936). Bavaria—Allescher (1884), Allescher and Schnabl (†), Britzelmayr (1885), Magnus (1898), Schaeffer (1800), Schrank (1789). Brandenburg—Hennings (1903), Sydow (Myco. March. No. 716). Hessen-Nassau—Von Braune (1797), Gärtner, Meyer, and Scherbius (1802). Prussia—Nitardy (1904). Saxony—Brick (1898), Krieger (Fung. Saxon. No. 69), Von Thümen (Myco. Univers. No. 2202). Silesia—Aderhold (1902), Schroeter (1888). Thuringia—Hennings (1903a).

Austria-Hungary: Winter (1884). Bohemia—Bodenath (‡) Corda (1842). Karnten—Jaap (1908). Lower Austria—Strasser (1900). Transylvania—Barth (‡). Tyrol—Bresadola (see Murrill, 1904), De Cobelli (1899), Von Dalla Torre, Von Sarnthein, and Magnus (1905), Von Höhnel (1909), Jaap (1901, 1908), Kerner (Fl. Exsicc. Austr.-Hung. No. 761), Von Sarnthein (1901). Voralberg—Von Dalla Torre, Von Sarnthein, and Magnus (1905).

Servia: Ranojevie (1902).

Italy: Rome—Lanzi (1902). Venice—Pollini (1824), Saccardo (1879).

Switzerland: Fries (1828), Murrill (1904, ‡), Neuweiler (1905), Ruffieux (1904), Schenk (‡), Secretan (1833).

Holland: Oudemans (1867, 1893).

Belgium: Kickx (1867).

France: Arnould (1893), Bigeard and Jacquin (1898), Clerc (1902), Desmazières (Pl. Crypt. Fr. No. 2155), Gillet (1874), Gillot and Lucand (1888), Guillemot (1893), Matruchot (1902), Paulet and Léviellé (1855), Persoon (1799), Quélet (1886, 1888), Roumeguère (Fung. Gall. Exsicc. No. 855).

Spain: Colmeiro (1889).

ASIA.

Siberia: Hennings (1898), Von Thümen (1878).

East Indies: Java—Kops and Van der Trappen (1849).

AUSTRALIA.

Victoria: Cooke (1892), McAlpine (1895).

SOUTH AMERICA.

Argentine Republic: Spegazzini (1899).

Brazil: Rick (1904).

NORTH AMERICA.

Canada: Dupret (see Lloyd, 1906a, 1908b), Fowler and Langton (see Lloyd, 1909), Macoun (see Murrill, 1904).

British Columbia—Hill (‡).

New Brunswick—Hay (§).

Nova Scotia—Somers (1880).

Ontario—Dearness (‡), Macoun (‡).

Newfoundland: Robinson and Von Schrenk (§).

Mexico: Egeling (‡).

These reports indicate that *Lenzites sepiaria* is present throughout Europe; that it is prevalent and probably widely distributed in Australia and the neighboring islands, including the East Indies, and is widely distributed in South America. In North America it is undoubtedly present in Canada and Newfoundland throughout the coniferous forests; and it is probably equally prevalent in the coniferous forests of Mexico.

The Fungus in the United States.

Lenzites sepiaria has been reported from and collected in the various States of this country as follows:

Alabama: Earle (1901), Earle and Baker (‡), Humphrey (‖ No. 5295), Von Schrenk (see Murrill, 1904, ‡), Underwood and Earle (1897).

Arizona: Burrall (‖ Nos. 1089, 1156, 1162, 1163, 1168), Hedgcock († ‖ No. 4889).

Arkansas: Humphrey (‖ No. 5646).

California: Harkness and Moore (1880), Hedgcock (‖ No. 1889), Palmer (§).

Colorado: Baker (‡), Baker, Earle, and Tracy (†), Bethel (‡), Harper (¶), Hartley (‖ Nos. 1641, 1678, 1775), Hedgcock (‖ Nos. 576, 577, 618, 619, 620, 651, 852, 889, 921, 1606, 1626, 1632, 1634, 1635, 1930), Hedgcock and Hartley (‖ Nos. 609, 692, 694, 697), Hodson (‖ No. 1177), Knaebel (see Lloyd, 1908a), Underwood and Selby (‡, see Murrill, 1904).

Connecticut: Spaulding (‖ No. 2275), White (1905), Miss White (see Murrill, 1904).

Delaware: Commons (†).

District of Columbia: Spaulding (‖ No. 106).

Florida: Britton (see Murrill, 1904, ‡), Calkins (†), Fisher (see Lloyd, 1907), Noble (see Lloyd, 1902).

Georgia: Humphrey (‖ Nos. 5047, 5059, 5090, 5091, 5117, 5194).

Idaho: Hedgcock (‖ Nos. 877, 978, 979, 4452, 4725, 4741, 4742).

Illinois: Clute (see Lloyd, 1909), Harper (¶), Moffatt (1909).

Indiana: Harper (¶). Moffatt (1909).

Iowa: Bessey (1884).

Louisiana: Hedgcock (‖ Nos. 363, 373, 394, 404), Humphrey (‖ Nos. 5328, 5333, 5385, 5687), Langlois (†, 1887).

Maine: Blake (‡, see Ricker, 1902, see Sprague, 1858), Harvey (see Ricker, 1902), Harvey and Knight (1897), Ricker (1902), Von Schrenk (†), Spaulding (‖ Nos. 103, 107, 108), Sprague (1858), Miss White (‡, see Murrill, 1904), White (1902).

Maryland: Graves (‖ No. 3735), Lakin (see Lloyd, 1907), Scribner (†).

Massachusetts: Farlow (1876), Huntington (see Lloyd, 1907), Mackintosh (see Lloyd, 1907), Pierce (see Lloyd, 1907), Smith (see Lloyd, 1906a), Webster (§).

Michigan: Harper (¶), James (see Lloyd, 1902), Longyear (1904), Von Schrenk (‖ No. 1109).

Minnesota: Arthur (†, 1887), Holway (‡), Hedgcock (‖ Nos. 4101, 4121, 4122, 4162).

Mississippi: Earle (‡), Hedgcock (‖ No. 332), Humphrey (‖ No. 5281).

Missouri: Glatfelter (1906), Spaulding (*).

Montana: Anderson (‡, see Murrill, 1904), Blankinship (‡), Mrs. Fitch (‡), Hedgcock (‖ Nos. 955, 966, 4240, 4252, 4299, 4322, 4380, 4408, 4409, 4443, 4528, 4531, 4617, 4645, 4688, 4694), Rydberg and Bessey (‡, see Murrill, 1904).

Nebraska: Bates (see Lloyd, 1909), Webber (1890), Williams (†).

New Hampshire: Jones (see Lloyd, 1906a), Minns (‡), Sargent (see Lloyd, 1908a), Spaulding (‖ Nos. 2221, 2919, 2920, 2950), Warner (see Lloyd, 1906a).

New Jersey: Britton (1881), Ellis (North American Fungi No. 1), Von Schrenk (|| No. 105), Sterling (see Lloyd, 1908a).
New Mexico: Hedgcock (|| Nos. 259, 454, 543, 808).
New York: Clinton (†), Clute (see Murrill, 1904), Dobbin (see Lloyd, 1907), Harper (¶), Humphrey (see Lloyd, 1907), Jeliffe (see Murrill, 1904), Peck (** 1869, 1879, 1883, 1884, 1893, 1899, 1901), Smith (†), Spaulding (|| Nos. 2043, 2051, 2241, 2253), Underwood (see Murrill, 1904), Underwood and Cooke (‡), Weld (see Lloyd, 1906a).
North Carolina: Curtis (§, 1867), Graves (|| No. 3544), Humphrey (|| No. 5021), Ravenel (Fung. Amer. No. 208).
North Dakota: Brenckle (see Lloyd, 1907), Waldron (see Lloyd, 1906a).
Ohio: Bubna (see Lloyd, 1908b), James (†), Morgan (1883).
Oregon: Hedgcock (|| Nos. 36, 1714, 1731, 1732, 1748, 1752, 1825).
Pennsylvania: Dallas (see Lloyd, 1906a), Murrill (‡), Von Schweinitz (1832).
Rhode Island: Bennett (1888).
South Carolina: Curtis (§), Humphrey (|| No. 5021), Ravenel (Fung. Amer. No. 208).
Tennessee: Murrill (1904).
Texas: Billings (‡), Von Schrenk (1904), Spaulding (|| No. 444), Wright (§).
Vermont: Frost (††), Pringle (§), Spaulding (|| Nos. 2090, 2091, 2234, 2235, 2317, 2904, 2905).
Virginia: Humphrey (|| Nos. 5005, 5007), Murrill (‡).
Washington: Harper (¶), Humphrey (|| Nos. 5860, 5869, 5934, 5964, 6009, 6048), Piper (see Lloyd, 1902).
West Virginia: Millspaugh (1892), Millspaugh and Nuttall (1896).
Wisconsin: Cheney (‡‡), Harper (¶), Neumann (‡‡, 1905).

The above-cited localities show that *Lenzites sepiaria* is prevalent throughout the United States wherever coniferous forests grow or coniferous species of wood are used.

KINDS OF WOOD ATTACKED BY LENZITES SEPIARIA.

Lenzites sepiaria is generally understood to be limited to species of coniferous wood, while *L. vialis* Peck usually is found only on deciduous species. Like other rules, this one has its exceptions, and *L. sepiaria* is occasionally found on the wood of some deciduous trees. The records available show that it has been found upon the wood of the following species:

Abies sp.—Farlow and Seymour (1888), Saccardo (1898), Waghorne (*).
A. balsamea (Linn.) Mill.—Harper (¶), Spaulding (|| Nos. 107, 925, 2043).
A. grandis Lindl.—Hedgcock (|| Nos. 1732, 1931).
A. lasiocarpa (Hook.) Nutt.—Hedgcock (|| Nos. 619, 621, 921, 4291, 4645, 4696).
Alnus sp.—Rick (1898).
Juniperus pachyphloea Torr.—Burrall (|| No. 1162).
Larix laricina (Du Roi) Koch—Neumann (1905), Von Schrenk (1904).
L. occidentalis Nuttall—Hedgcock (|| Nos. 4697, 4725).
Picea sp.—Millspaugh (1892), Peck (**).
P. canadensis (Mill.) B. S. P.—Arthur (1887), Farlow and Seymour (1888).
P. engelmanni Engelm.—Baker, Earle, and Tracy (†), Hartley (|| Nos. 1606, 1641, 1678), Hedgcock (|| Nos. 577, 852, 966, 1632, 1635, 4252, 4322, 4617), Hedgcock and Hartley (|| Nos. 609, 692, 694, 697), Hodson (|| No. 1177).
P. excelsa Link.—Spaulding (*), Thesleff (1894), Von Thümen (Mycotheca Universalis No. 2202).

P. mariana (Mill.) B. S. P.—Millspaugh and Nuttall (1896), Peck (1893), Spaulding (‖ Nos. 952, 2241, 2266).
P. rubens Sarg.—Spaulding (‖ Nos. 2091, 2205, 2221, 2234, 2235).
Pinus sp.—Ellis (North American Fungi No. 1), Farlow and Seymour (1888), Fries (1863, 1874), Frost (††), Gillet (1874), Gillot and Lucand (1888), Harper (‡‡), Karsten (1876), McAlpine (1895), Neumann (‡‡), Sommerfeldt (1826).
P. divaricata (Ait.) Du Mont de Cours—Hedgcock (‖ Nos. 4162, 4209).
P. echinata Mill.—Hedgcock (‖ Nos. 363, 373), Humphrey (‖ Nos. 5059, 5281, 5333), Von Schrenk (1904).
P. glabra Walt.—Hedgcock (‖ No. 372).
P. lambertiana Dougl.—Hedgcock (‖ No. 1889).
P. monticola Dougl.—Hedgcock (‖ No. 4694).
P. murrayana Oregon Comm.—Hedgcock (‖ Nos. 576, 618, 889, 955, 1930, 4240, 4275, 4408, 4741).
P. palustris Mill.—Bates (1907), Von Schrenk (1904), Spaulding (‖ No. 444).
P. ponderosa Laws.—Anderson (‡), Hedgcock (‖ Nos. 808, 978, 979).
P. rigida Mill.—Peck (1893).
P. sibirica Mayr.—Saccardo (1898).
P. silvestris Linn.—Saccardo (1898), Thesleff (1894).
P. strobus Linn.—Peck (1893), Von Schrenk (‖ No. 1109), Spaulding (‖ Nos. 2919, 2950, 2951).
P. taeda Linn.—Hedgcock (‖ No. 394), Humphrey (‖ Nos. 5117, 5328), Von Schrenk (1904).
P. virginiana Mill.—Graves (‖ No. 3735).
Populus alba Linn.—Farlow and Seymour (1888), Morgan (1883), Saccardo (1898).
P. deltoides Marsh.—Farlow and Seymour (1888), Peck (1884), Saccardo (1898).
P. tremuloides Michx.—Hedgcock (‖ Nos. 620, 1634), Spaulding (‖ No. 2317).
Pseudotsuga taxifolia (Lam.) Britton—Harper (¶, ‡‡), Hartley (‖ No. 1775), Hedgcock (‖ Nos. 36, 651, 877, 1636, 1714, 1731, 1752, 1825, 4299, 4409, 4443, 4452, 4528, 4531, 4688, 4742, 4889), Humphrey (‖ Nos. 5860, 5869, 5934, 5964, 6009).
Salix sp.—Bessey (1884).
S. discolor Muehl.—Farlow and Seymour (1888), Peck (1884), Saccardo (1898).
Tsuga canadensis (Linn.) Carr.—Blake (‡), Dudley (1887, 1889), Farlow and Seymour (1888), Frost (††), Graves (‖ No. 3544), Millspaugh (1892), Millspaugh and Nuttall (1896), Neumann (1905), Peck (1893), Saccardo (1898), Von Schrenk (1904), Spaulding (‖ Nos. 103, 972, 2085, 2090, 2204, 2220, 2253), Underwood and Cook (‡).
T. heterophylla (Raf.) Sarg.—Hedgcock (‖ Nos. 1748, 4380, 4776).

The above reports and collections show that *Lenzites sepiaria* may attack the wood of the species of Abies, Alnus, Juniperus, Larix, Picea, Pinus, Populus, Pseudotsuga, and Tsuga. It may be expected to occur occasionally on the wood of Chamaecyparis, Cupressus, Libocedrus, Sequoia, Thuja, and Taxodium. Whether it may also attack the wood of deciduous species other than those belonging to the genera Alnus, Populus, and Salix is uncertain; specimens of fungi, which are so poorly developed that it is impossible to identify them with certainty, have been collected upon a number of the deciduous species.

This fungus is rather rarely found on the wood of living trees (Hahn, 1908, Hennings, 1903a, 1903b, Von Schrenk ‖ No. 105, Spaulding ‖ No. 2266), and so far as the writer knows has never been

mentioned as occurring parasitically. Hedgcock (|| No. 1632), however, found an instance where a tree of *Picea engelmanni* about 4 inches in diameter was sharply bent by snow and was unable to straighten up when the weight was removed. The bark became loosened on the top of the bend, and this gave an entrance for the fungus, which worked downward in the injured wood tissues until only a small portion of the lower side of the trunk was alive (fig. 1). There seems to be no doubt in this case that the fungus was a wound parasite. Six inoculations into living trees of *Pinus palustris* made by the writer were wholly without result. For all practical purposes *Lenzites sepiaria* is a saprophyte, attacking timber which is piled for seasoning, or which is in use but exposed to the elements.

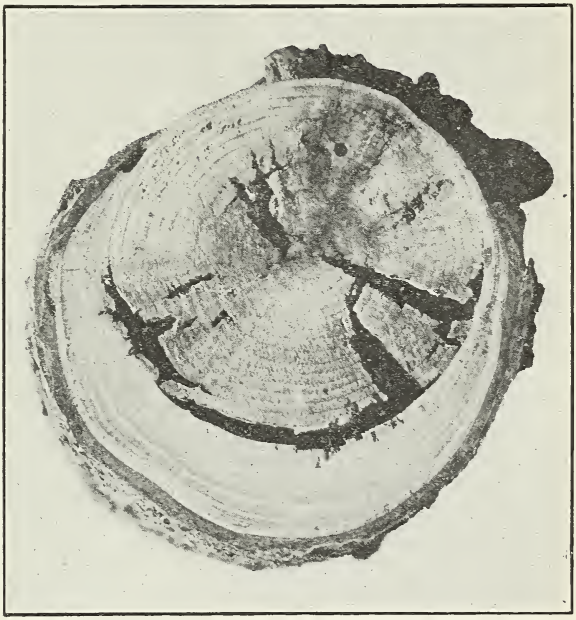

Fig. 1.—Cross section of living tree of *Picea engelmanni*, showing parasitic action of *Lenzites sepiaria*. The five annual rings on lower side are alive, but the inner one shows the encroachment of the fungus.

Lenzites sepiaria has been found by the writer upon the heartwood of *Tsuga canadensis* (|| No. 2085) and *Larix laricina*, and it often attacks the outer layers of the heartwood in many other species. Whether it is able to rot the resinous heartwood of the southern pines seems questionable. The writer has seen no instance where this had taken place, except in the outer layers of heartwood which were not so completely filled with resin as the inner ones.

METHOD OF ENTRANCE AND RATE OF GROWTH OF LENZITES SEPIARIA.

Lenzites sepiaria is undoubtedly able to penetrate wood where it is cut across the grain, and under most conditions can probably enter radially if there is some small break in the fibers so that it can get between them. The evidence seems to show that when it enters upon the side of a timber it does so by means of season cracks.

These afford a very ready access to the interior tissues, since they often extend to the heartwood, or even into it (Pl. II, figs. 1 and 2; and Pl. III, fig. 3). The season cracks are especially favorable for the development of the fungus, as they dry out much more slowly than do the outer layers of wood, and thus give the spores a chance to germinate and to push the germ tube into the adjacent wood cells before the air is too dry for further development.

Lenzites sepiaria grows very rapidly under favorable conditions. Observations on newly cut, green railroad ties have shown that fully developed normal sporophores will form within five months' time upon such timbers. Artificial inoculations made by the writer also resulted in the formation of sporophores within five months (Pl. III, fig. 2). This remarkably short time for the development of a serious wood-rotting fungus is of course possible only under the most favorable conditions.

THE FUNGUS.

ITS NAME.

Lenzites sepiaria has been known in Europe for many years, being easily traced back to 1786, and with less certainty to a considerably earlier date. It has been placed in a number of different genera, according to the ideas of the various authors who have written about it. It was called *Agaricus sepiarius* by Von Wulfen (1786), who first named it; Persoon (1800) called it *Merulius sepiarius;* Fries (1815) changed it to *Daedalea sepiaria,* but later (1838) changed it again to *Lenzites saepiaria;* Karsten (1876) at first used the name *Lenzites saepiaria,* but later (1882) changed to *Gloeophyllum saepiarium,* and still later (1889) changed to *Lenzitina saepiaria;* Murrill (1904) used the name *Sesia hirsuta,* but later (1905, 1908) changed to *Gloeophyllum hirsutum.* The matter has not been investigated thoroughly enough for the writer to venture an opinion as to the merits of the various names. He therefore uses the name *Lenzites sepiaria,* which is used and accepted by most botanists.

THE SPOROPHORES.

The sporophores are rather small for a wood-rotting fungus. They rarely project more than 2 inches from the substratum, and are commonly long, narrow, shelf-like formations, extending horizontally from the surface of the wood. They are frequently compound or are clustered very closely together, and are especially numerous on the ends of affected timbers (Pl. I, fig. 1). When they are on the sides of the timber they are almost certain to be situated in season cracks (Pl. III, fig. 3). Sometimes, on a very badly rotted log, many sporophores situated in a single season crack fuse

laterally and form a single fruiting body, extending the entire length of the log. The usual form of the fruiting surface is that of irregularly branching gills, but cases can be found where it is in the form of more or less regular pores. On the other hand, the gills are sometimes as regular as those of most of the Agaricaceæ. One case was noted where the sporophores grew on the upper horizontal surface of a square timber and had the hymenium in the form of spiny projections. Similarly shaped bodies have been obtained in cultures (Pl. IV). The sporophore is perennial. When the conditions for growth are favorable, a new development takes place on the edge of the fruiting body and its under surface. There is a very marked difference in the color of the sporophore, depending upon its age. The youngest mycelium is snow-white; then, as age increases, the color turns quite rapidly to a yellowish white, then to a deeper yellow, finally to a brown, and in very old specimens it may be almost black. Very often the edges of the sporophores are yellowish white in color, showing that a new growth has taken place very recently. During sporulation the hymenium is yellowish white (Pl. I, fig. 2), and this color is a very good indication that spores are being given off. Sporophores collected in Missouri, in January, when placed in moist chambers gave off spores very abundantly within a few hours, seeming to show that sporulation in northern climates takes place at almost any time when there is enough heat and moisture for the tissues to carry on their functions.

Sporophores of *Lenzites sepiaria* may remain dry and apparently lifeless for a long period and still be able to produce viable spores under favorable conditions. This power to revive after long periods of inactivity is known to be not uncommon with the wood-inhabiting fungi. Buller (1909) found this property to exist to a remarkable degree in certain species: *Daedalea unicolor* (Bull.) Fr. recovered after desiccation for four years. *Lenzites betulina* (L.) after three years, and various others for periods varying from one week to three years. Rumbold (1908) found that specimens of *Lenzites sepiaria* which had been kept dry for 17 months, when moistened were able to produce viable spores. Moreover, they were able to repeat this performance after being dried again and lying a short time inactive. The writer obtained abundant spores in April, 1910, from fruiting bodies which in April, 1908, had been placed in a petri dish and collections of spores made. They soon dried out and had remained thus ever since in a dark drawer. Two years later they were again moistened and spores were produced as above stated. Tests of viability were not made, but Buller (1909) states that the production of spores is an indication that sporophores are alive. This power of reviving after long periods of drought is of considerable

importance, since it means that decayed timbers are a constant source of infection and should be destroyed instead of being left lying upon the ground.

The number of spores produced by an ordinary-sized sporophore of *Lenzites sepiaria* is literally millions. Buller (1909) has shown that a sporophore of *Daedalea confragosa* (Bolt.) Pers., about 2 square inches in area, produced nearly three-fourths of a billion of spores when revived after desiccation. This is much like *Lenzites sepiaria* in the character of its sporophores and may be taken to indicate very roughly the conditions occurring with the latter species. This emphasizes the fact that where there are fruiting bodies of *Lenzites sepiaria* there surely are spores everywhere in the vicinity, and no timber can be expected to remain free from them for any great length of time. Hence, it is doubly wise to destroy all decayed timbers.

DEVELOPMENT OF THE SPOROPHORES.

The first visible sign of the effects of this fungus is a blackening of the ends of the affected timbers over a space of several square inches. This blackening is quite noticeable to a close observer, and is present for some little time before the mycelium appears on the surface. After a few weeks, when there is sufficient moisture in the air, a tiny tuft of white mycelium appears somewhere on the blackened area. This grows larger within a few days if the moist condition continues, until it is about one-fourth inch across; then the tuft thickens until it stands out from the surface of the wood about one-eighth inch. The development of the gills begins early, goes on rapidly, and continues until the sporophore has reached its growth. The gills begin to form while the mycelial mass is still small (one-eighth to one-sixteenth inch), as soon, indeed, as there is room for a gill to be formed beneath. When the gills are well started, and sometimes before, the older parts of the mass turn to a light-brown color, meanwhile passing through the various shades of yellow. In Texas the entire development of the mature fruiting body may take place within 10 days from the very first appearance of the mycelium on the outside of the timber. After the first sporophore has formed it is usually not long before several others are produced immediately adjacent to it.

Some notes made by the writer on the rapidity of the growth of the sporophores in Texas are of interest. On one timber several tiny masses of white mycelium were barely visible on one of the blackened spots at the end of the timber. Seven days later the gills were beginning to form, and the oldest parts had turned brown. On the eleventh day several distinct sporophores which had formed during this time had fused into a single one, three-fourths inch long and

three-sixteenths inch wide, with numerous gills. On another timber tiny masses of white mycelium were visible when the observations were started. Six days later these masses had developed into a single large sporophore nearly 2 inches in length. On still another timber the first traces of gills had formed; four days later there were 16 gills. These observations were made at a time when the weather was very favorable for the growth of the fungus, there being a shower every day, with hot, muggy weather between the showers. Commonly several small pilei form at the same time very closely together, and these then fuse into one or two large ones which afterwards show no signs of their compound nature. The gills first form as very slight ridges on the under side of the mycelial mass, then these ridges grow higher until they form the fully developed anastomosing gills. One very curious case was noted where a railroad tie, with a newly formed sporophore upon it, had been turned with its former upper surface underneath, so that the gills were on the upper instead of the under surface. When found, the gills had just begun to produce a new growth of mycelium. On the sixth day new gills began to form on the former upper surface of the fruiting body; on the eighth day the transformation was complete, and one would never suspect the change which had taken place, the pileus being exactly like a normal one, except for a slight increase in thickness.

THE MYCELIUM.

The hyphæ of this fungus are very plentiful in the rotten wood, but are especially found in the medullary rays and the large cells of the wood. Very often an entire cell cavity is filled with a tangled mass of mycelium. The mycelium consists of two distinct kinds—a larger, dark-colored form, in which no contents can be perceived; and a smaller, colorless form, with a more or less granular content. The former is apparently the older form, and the color of the wood tissues where it is at all plentiful is a dark brown, evidently caused by the presence of so much dark-colored mycelium within, and not by any secretion or infiltration substance. The colorless form is evidently the younger and more active portion, and is much more often found, being very common in badly rotted wood. The hyphæ measure from 2 to 6 microns in diameter.

THE SPORES.

Experience gathered during a number of trips to Texas at different times of the year shows that the spores are produced abundantly there from June to November. The spores were collected by placing wet sporophores in moist chambers upon glass slides. Under these conditions the spores were given off very freely. The spores en

masse are pure white; they are ellipsoid, with more or less variation; many are slightly curved, and they often have a slight remnant of the pedicel attached to them, giving them a pointed appearance at the basal end; they are quite uniform in size and shape, and measure about 3.5 to 4 by 6 to 12 microns. Some are slightly club-shaped, but this is not common. When first set free their contents are finely granular.

GERMINATION OF THE SPORES.

After lying in water or a dilute solution of sugar for some hours, the contents of the spores become coarsely granular and 1 to 3, or in rare cases 4, guttules are formed. The spores did not germinate in very dilute solutions of sodium chlorid, but a solution of cane sugar up to 2 per cent and tap water gave results. In this solution the spore swells and pushes out a germ tube, which branches as it develops. Septa are formed, but they are not frequent. The germ tubes measure about 2 to 3½ microns in diameter, or about the same as that of the spores themselves at this time. A spore commonly produces a single germ tube, but two may be given off, one from either end. More than two germ tubes from a single spore have not been noted. The germ tube soon branches and forms a more or less extensive mycelium. The branches seem to arise from almost any point and are not especially abundant. In cultures the mycelium commonly has coarsely granular contents, which are retracted to the middle of the hyphæ. The germ tubes and hyphæ are quite uniform in size throughout their length.

CULTURES.

On July 24, 1904, while in Texas, the writer was able to collect spores in sufficient quantities for cultural experiments. The first test was made in hanging drop cultures in water. This water was collected from the roof of the house and stored in a galvanized-iron cistern. The cultures resulted in flat failure, although the spores did undergo some changes. After lying for an hour or so in the water their contents became coarsely granular and from 1 to 3 or 4 guttules were formed. No facilities were at hand for weighing small quantities of material, but a dilute solution of cane sugar and one of sodium chlorid were made. These were certainly less than 1 per cent solutions, and were presumably much weaker. Because of enforced absence the next day it is not known how long before germination took place. Judging from the length of the germ tubes, it must have been within 24 hours after the sowing of the spores. The cultures in sugar solution were the only ones that grew, and of these only two showed germination. The cultures were repeated with no results, so the entire study was necessarily made from these two

cultures. Later tests made with spores collected from sporophores brought into the laboratory in January from wood in the vicinity of St. Louis gave better germinations with sugar solutions up to and including 2 per cent of sugar by weight. In these tests the spores showed all of the previously described phenomena. Germination took place in about 30 hours and about 25 per cent of the spores germinated. The ungerminated spores remained apparently unchanged except for a slight swelling. Recently germination in tap water has been observed by the writer.

In the culture work with this and a number of other wood-rotting fungi in 1903 and 1904 the writer (1905) found it much easier to secure cultures from small masses of actively growing mycelium than from the spores themselves. His procedure is to choose actively sporulating, fruiting bodies, cut small pieces from them, pass quickly through the flame of a Bunsen burner, and place in a petri dish containing warm agar or gelatin media. If done skillfully a fair percentage of the plates will produce pure colonies of the fungus by the outgrowth of hyphæ onto the agar from the original mass of mycelium. The same method may be used with tubes of sterilized wood. Another method is to take small pieces of wood which is in the early stages of decay and contains active mycelium and use them in place of the bits of sporophore.

A large number of such cultures have been made upon sterilized wood in test tubes. Many of these cultures, owing to contaminations which it was next to impossible to exclude in the field, have failed, and all have failed to produce normal sporophores, which is the experience of others also (Rumbold, 1908); and a few cultures have developed spinelike fruiting surfaces instead of the usual gill form. (Pl. IV.) This form has been found in natural conditions in the field, as mentioned earlier in this bulletin.

Rumbold (1908) found that *Lenzites sepiaria* is very sensitive to alkaline media when grown in pure cultures. A number of different experiments uniformly gave the same results with this species. It was found that even with one-fourth of 1 per cent of sulphuric acid it grew luxuriantly. This chemical has been recently used successfully as a fungicide in dilute solutions for certain of the fungi (Anonymous, 1907; Kraemer, 1906; Spaulding, 1908b), and formerly was used more or less commonly for the same purpose. (Baierlacher, 1876; Bouchard, 1896; Degrully, 1895a and 1895b; Gellin, 1896; Guillemot, 1893; Von Liebenburg, 1880; Lodeman, 1896; McAlpine, 1898; Oliver, 1881; Zoebl, 1879.)

INOCULATIONS.

Inoculations have been made with living and actively growing mycelium in various ways to test certain points in the life history of

this fungus. The question of the possible parasitism of live trees has been tested by making inoculations into living trees of longleaf pine. These were made by boring holes into the trees with a small bit, then placing in the holes pieces of rotted wood containing active mycelium, and plugging the holes to prevent too rapid drying out. Similar inoculations were made in freshly felled trees to determine the time necessary for the development of sporophores. Absolutely no results could be detected from six inoculations made in the living trees, thus seeming to prove that *Lenzites sepiaria* is a true saprophyte and incapable of attacking living wood. Hedgcock (‖ No. 1632) collected a specimen which seems to show it to be very weakly parasitic. (Fig. 1.) This conclusion is borne out by the results of the inoculations in felled trees. In less than five months from the time of inoculation fruiting bodies were found growing upon the ends of the plugs used to keep the material from drying out. The plugs were about 3 inches in length and the mycelium had grown through the wood for that distance, completely rotting it for a portion of the way, and then forming fruiting bodies on the outside. (Pl. III, fig. 2.) The plugs were made of green wood taken from the tree in which the inoculations were made. The wood of the tree itself was apparently not attacked, this being probably due to the earlier death of the wood of the plug. Moreover, railroad ties, the time of cutting of which was exactly known, had sporophores of this fungus within five months of the time when cut from the green trees. When one considers that some little time must elapse before the wood of the perfectly green tree is dead, he may gain an idea of the rapidity with which this fungus destroys timber under favorable conditions. This is especially true of railroad ties and timbers which are placed under very favorable conditions for the growth of fungi, and which in Texas usually last only about 12 to 24 months in use.

THE DECAYED WOOD.

EXTERNAL APPEARANCE OF TIMBER.

A timber which is affected, but which as yet has no sporophores upon it, has a very characteristic appearance. The ends are generally the parts first to become affected. Here will be seen on dry ties a blackened area of a more or less irregular outline. This may be only an inch or two across, or may be larger, but it is never found extending into the heartwood. To the experienced person it is a sure indication that there is within an affected spot and that sporophores will soon be formed somewhere upon the discolored area. The appearance is as if the wood beneath were water soaked. The wood has been so decomposed that the smallest quantity of water makes it look wet.

The affected wood is also more darkly colored than normal sound wood, and this undoubtedly helps to give the discolored appearance on the exterior. It can not be said that these discolored spots always have a direct relation to the season cracks, but this is very often the case. Whether the spots are a result of the season cracks is uncertain, but in many instances at least they seem to be.

INTERNAL APPEARANCE OF TIMBER.

This fungus attacks coniferous wood wherever the conditions are at all favorable for the growth of the fungus, and it soon reduces the wood to a dry, brown mass, retaining but little resemblance to its normal appearance (Pl. III, fig. 1). The decay has been called a dry rot. It has always been found that when fruiting bodies have been formed at least a small portion of the wood has been completely rotted. At first the tendency is to form small pockets of rotted wood in the interior of the attacked timber, then to spread from these into the adjacent wood, spreading longitudinally faster than radially. The writer found that rot extended longitudinally in the wood from the fruiting bodies at least a foot, and sometimes for twice that distance, but commonly between these limits.

In the early stages of decay the early spring wood of the annual rings sometimes may be completely rotted and reduced to an amorphous powder, while the late summer wood, which is more compact, is almost wholly unaffected. The annual rings may then be very easily separated from each other with the fingers, and it is impossible to cut a block of such wood out of the affected timber, owing to the rings falling apart as soon as cut across. This peculiar action of *Lenzites sepiaria*, the writer believes, is due simply to the structure of the annual ring, which in some species of trees exhibits distinct differentiation between the early, porous portion and the later, more compact portion. Boiling tests made by the writer (1906) showed conclusively that the lignin of the early wood is more easily dissolved than is that of the late wood of the same annual ring, where the two parts are at all distinct. The degree of differentiation in the annual ring seemed to be the controlling factor in this difference in solubility of the lignin. Attention was called to the fact that these tests furnish an explanation for the disintegration of the early wood of the annual ring by certain wood-rotting fungi, while the late wood is but slightly decayed.

The affected wood assumes a shade of light brown, and small cracks run irregularly across the wood fibers, indicating that considerable shrinkage has been caused by the action of the fungus upon the wood (Pl. IV). The infections nearly always take place in season cracks, as is very clearly shown by the position of the fruiting bodies (Pl.

III, fig. 3) and the pockets of the rotted wood within (Pl. II, figs. 1 and 2). More or less extensive sheets or strings of matted mycelium may be found throughout the rotted wood. These mats are of varying shades of brown and yellow. A cross section of a decayed timber shows very plainly that it has been rendered totally unfit for use (Pl. III, fig. 1). In the earlier stages of the disease there are in the sapwood more or less numerous and extensive patches which have turned a dark-brown color, while large fissures run irregularly both radially and between the annual rings, showing that the fungus has caused some very serious changes in the structure of the wood. These patches of rotted wood are generally arranged in pockets with sound wood between them (Pl. II, fig. 2). As these pockets grow larger they extend radially faster than tangentially. This is partly owing to season cracks which frequently open for several inches in depth (Pl. II, fig. 1). In general the heartwood is not attacked (fig. 2), but in the last stages of the decay the outer layers of the heartwood may be more or less affected, owing probably to their not having fully assumed the characters of the older heartwood and also to season cracks opening directly into the heartwood (fig. 2). The outer rings of a peeled log are very commonly not rotted, while those farther in are almost completely disorganized. This difference may be explained by the fact that the sun soon dries out the external layers, so that the fungus has not enough water for its needs. While in the early stages of the rot the annual rings become separated from each other and the fall wood is little affected, in the last stages the fall wood also becomes completely decomposed and crumbles easily between the fingers. A log which is badly rotted at the end shows the fact by the very numerous cracks which are visible (Pl. I, fig. 1). It is noted that tree tops which have the bark left upon them have the sapwood completely rotted where the fruiting bodies show.

Fig. 2.—End of a new pine railroad tie, showing many sporophores of *Lenzites sepiaria*. Note season crack extending to heartwood; also freedom of heartwood from sporophores.

MICROSCOPIC EXAMINATION OF AFFECTED WOOD.

Radial sections of the rotted wood reveal almost no places where the mycelium has pierced the cell walls as is so common with other wood-rotting fungi. Instead, the hyphæ pass through the pits, this apparently being the rule. Cells and groups of cells, especially of the medullary rays, are often found with masses of the mycelium in their interior. The mycelium often forms an interwoven mass which completely fills the cell lumen.

Cross sections of the pits can be gotten only in tangential and cross sections of the timber. The tangential sections show the cross sections of the rays, and most of them have their component cell walls, especially near the middle, wholly destroyed and the cavity filled with mycelium matted closely together. The rotted wood is so brittle that no free-hand cross sections can be made.

The bordered pits have their closing membrane missing, and, as already stated, the mycelial strands pass freely through them. Very many pits have their borders cracked, with one to several openings running nearly to their periphery. The original opening of the pit is often enlarged, although this is not generally very noticeable. Sections of the wood in the last stages of decay show that the middle lamella is dissolved, thus allowing the cells to fall apart very easily.

The cell walls undergo some change which makes them exceedingly brittle, the razor breaking rather than cutting them. No elasticity is left in the tissues, the thickness of the razor being enough to cause the sections to break into small fragments, which still stick slightly together. The sections were cut free-hand, without embedding the material. Numerous tabular crystals lie directly upon the hyphæ of the fungus, which are apparently formed by the action of the fungus on the wood. These crystals dissolve in hydrochloric acid without effervescing.

MICROCHEMICAL TESTS OF AFFECTED WOOD.

Phloroglucin and hydrochloric acid give a bright red in the rotted tissues. Anilin sulphate and anilin chlorid give a bright yellow in the affected wood. Delafield's hæmatoxylin gives blue throughout. Chloriodid of zinc gives a blue color only in part of the tissues in early stages of the disease, but in later ones it gives blue throughout. This bluing occurs in the early wood of the annual ring, shading off as the late wood begins, then begins abruptly with the next annual ring. Mäule's potassium permanganate test gives a deep red in the healthy wood, but none whatever in the rotted parts. Thallin sulphate gives a yellow in the rotted wood. Resorcin with sulphuric acid gives a violet green not nearly so pronounced in the decayed

tissues as in the healthy ones. Carbazol with hydrochloric acid gives a violet red, deeper in the rotted than in the normal wood.

These tests seem to show that the fungus has extracted or disorganized the coniferin and the hadromal of the lignin, but has left the vanillin.

PROOF THAT LENZITES SEPIARIA CAUSES THE DECAY.

Every indication noted in the field showed that this fungus causes the peculiar form of dry rot which has been attributed to it. The sporophores are located so near the badly decayed places in the wood that there seems to be no doubt of the connection of the two. But this is far from accurate scientific proof. Artificial inoculations made by the writer in freshly felled sound green trees have gone far toward furnishing such proof. A fragment of rotted wood was used for inoculating material, being placed in a small hole bored in the side of the tree; the hole was then plugged with a piece of green wood cut from the same tree, and about 3 inches long. When cut open, five months later, it was found that the plug was badly rotted in the middle through its entire length, while the inoculating material touched it at the inner end, and on the outer end was a small but mature sporophore. (Pl. III, fig. 2.) Besides this, the writer has repeatedly grown pure cultures of *Lenzites sepiaria* upon sterilized wood blocks and has obtained in these cultures the same type of brown dry rot that is constantly associated with the fungus in the open air. (Pl. IV.)

FACTORS GOVERNING THE GROWTH OF WOOD-ROTTING FUNGI.

It is a matter of general knowledge among botanists that there are certain definite factors which control the growth and reproduction of the higher fungi. The more important of these factors may be called food, air, water, and temperature.

It may be said by way of summary that if any one of these factors is unfavorable, the wood-rotting fungi can not live any great length of time and can not grow at all.

Food materials.—Suitable nutritive materials are as essential to the existence of the fungi as they are for any other living organism. The food of the wood-rotting fungi consists of two classes of material, the contents of the wood cells and the wood cell walls themselves. The former consist of a very heterogeneous group of substances, such as starch, oil, protoplasm, tannin, sugar, minerals in soluble form, pitch, resin, crystals, etc. The wood-cell walls consist of a cellulose base or framework, with various laminæ strengthened with lignin, both substances being of a very complex nature. The wood-inhabiting fungi attack these various substances with great variability;

some take only the sugar and starch, and leave the cell walls nearly intact; others dissolve only the cellulose, others the lignin, and still others take all indiscriminately. The amount of stored food material present in the cell cavities of a living tree varies much with the season, at least in the temperate climates. It has been found that trees tend to store food material in large quantities in late summer and fall; in winter these supplies remain practically uniform in quantity; in spring, when the new growth is formed, they are rapidly and practically completely used up, the insoluble starch being changed into the soluble sugars. The sapwood is much richer in stored food matter than is the heartwood, which usually does not contain food materials in large quantities at any time. This fact partly explains the greater resistance of heartwood in general to the attacks of these fungi. The change of the insoluble material into some soluble form in the spring explains the fact that sapwood cut in spring or early summer usually rots very quickly, while the same wood cut in the winter does not rot so quickly, the soluble substances contained in the spring being much more readily attacked by the fungi than the insoluble ones present in winter.

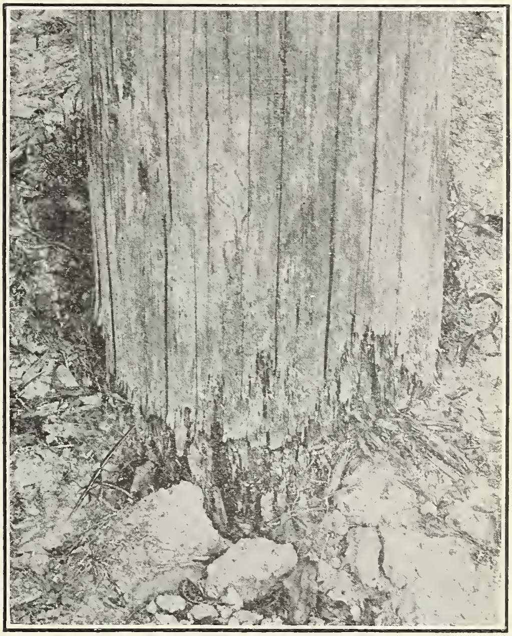

Fig. 3.—Lower end of telephone pole, showing decay at surface of ground while it is practically sound a short distance above.

Air supply.—Wood-rotting fungi are living organisms and need a certain amount of oxygen. Many bacteria are able to live beneath the surface of liquids, and obtain their oxygen from the liquid itself, but the wood-rotting fungi seem to be unable to do this, and must have free access to the atmospheric oxygen in order to exist in a normal manner. Hence, cutting off the air supply stops their growth, and even kills them if continued for a sufficient length of time. This fact explains why wood remains sound for hundreds of years when buried, or when lying on the bottoms of streams and lakes. The rafting of timber is said to have a marked effect in preventing decay, and this effect may probably be partly explained in the same way,

although it is likely that the food substances in the cell cavities are dissolved and partly removed by the solvent action of the water. Undoubtedly the air supply has much to do with the rotting of posts and similar timbers at or near the surface of the soil, while both above and below the surface decay is not so complete (fig. 3).

Water supply.—That a certain degree of moisture is essential for the growth of the wood-rotting fungi is as true of the so-called dry rot fungi as of any other. As soon as a certain piece of timber becomes well seasoned it loses much of its susceptibility to attack by fungi, and as long as it remains relatively free of water it will not rot. Instances are plentiful in Europe where timbers which are now sound have been in place in buildings for hundreds of years. Wood from the royal tombs of Egypt is perfectly sound after a period of over 5,000 years. This fact can be explained in no other way than that it was well seasoned when put in place and has been protected from moisture ever since.

Temperature.—A fourth condition is requisite for the growth of wood-rotting fungi, namely, a favorable temperature. These fungi can grow at ordinary temperatures in most countries, but they make little or no growth at freezing point and below. Many of them appear to have an upper limit even in outdoor temperatures at which they do not thrive. In the usual spring, summer, and autumn weather of this country the wood-rotting fungi thrive, but in winter growth ceases except in the warmer sections, where it probably continues all the time.[a]

METHODS OF PREVENTING THE DECAY CAUSED BY LENZITES SEPIARIA.

The decay of timber caused by *Lenzites sepiaria* is brought about by the action of the vigorously growing mycelium in breaking down the wood tissues and utilizing certain of their constituents in its own life processes. Consequently, anything which influences the growth and vigor of the fungus has a direct influence on the rate and extent of decay which the fungus can cause. It has been already stated that four essential factors govern the growth of *Lenzites sepiaria*, and therefore control the decay caused by it. Of these four factors only temperature may not be more or less regulated in timber which is in service, or while such timber is being prepared for service.

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[a] Falck (Die Lenzitesfäule des Coniferenholzes) gives some specific data on the maximum temperature for *Lenzites sepiaria*. He found that the mycelium in dry wood resisted an exposure of two hours to a heat of 97° C., nearly the boiling point of water; but mycelium in agar cultures was killed by 10 hours' exposure to 63°, and by 2 hours at 75°. The optimum temperature for germination of the spores is between 30° and 34° C., while the optimum for the mycelium in cultures is 35° C., and the growth minimum and maximum are 5° and 44° C., respectively.

The food supply can be effectively regulated by cutting the timber at the time when the trees either have their stored food materials in smallest quantity or else have them in the least available form, namely, late summer, autumn, and winter (Zon, 1909); but local conditions may modify the time of cutting to some extent. The supply of air can be regulated to some extent, the floating of timber being one of the most practical methods of such regulation. The water supply is probably the most easily regulated of any factor, the seasoning of timber being the most practical method of regulating it before it is placed in service. While in service, a number of methods are available, according to the location of the timber; for railroad ties, a well-drained roadbed (Dudley, 1887; Fernow, 1890; Von Schrenk, 1902); in other locations the seasoning of timber followed by painting or external coating with preservative substances (Dudley, 1887; Roth, 1895; Von Schrenk, 1902); the use of composite timbers instead of single large ones, leaving beams without boxing them in, and similar expedients are all thoroughly practicable methods of keeping the water content below the danger point.

SEASONING OF TIMBER.

It is a well-known and unquestioned fact that well-seasoned timber is much more durable than green timber of the same kind. The most important result of seasoning is the marked reduction of the water content to a point unfavorable for the rapid growth of wood-rotting fungi. Green coniferous timber contains 40 to 50 per cent of water (calculated on the dry weight of the wood) under ordinary conditions. Air-seasoned coniferous timber contains 10 to 25 per cent of water (Smith, 1908; Eastman, 1908; Sherfesee, 1908c; Hatt, 1907; Tiemann, 1907; Grinnell, 1907; Fernow, 1897). Air seasoning removes one-half to two-thirds of the total water content, lowers the water content especially of the outer layers of wood, and to a large extent prevents the infection of a sound timber; but there is danger of such infection occurring at any time when the timber becomes wet and absorbs enough water to very decidedly raise the water content.[a]

Seasoning is efficient as a method of preventing decay by *Lenzites sepiaria*. It must be done as rapidly as possible, especially in the Gulf States. To this end, open piling (Von Schrenk and Hill, 1903) is far better than the usual close method. It is necessary in eastern Texas to assist seasoning as much as possible, as green timbers will rot in five or six months if piled closely. In the Northern States seasoning progresses more slowly, but with less danger from this fungus.

Kiln drying is here considered as a rapid method of seasoning, the result being identical by either kiln drying or air drying.

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[a] Falck, Die Lenzitesfäule des Coniferenholzes, 1909, states that the mycelium of *Lenzites sepiaria* will remain alive in a dry decayed timber for two to three years.

FLOATING OF TIMBER.

The immersion of timber in water has long been held to increase its durability (Dudley, 1887; Fernow, 1890). Such timber seasons quickly after being removed from the water (Von Schrenk and Hill, 1903). It appears that the immersion of timber for several weeks or months will decrease the decay caused by *Lenzites sepiaria*, although no experiments have been made to determine this point.

TREATMENT WITH CHEMICALS.

The treatment of timber with solutions of chemicals which have a deleterious action on the wood-rotting fungi is by far the most efficient method of preventing decay. There is absolutely no question as to the efficiency of this method, as numerous tests show. The following publications of this department may be cited in this connection: Crawford, 1907a, 1907b; Nelson, 1907; Von Schrenk, 1902, 1904; Sherfesee, 1908a, 1908b; Smith, 1908; Weiss, 1907, 1908. Since this fungus will not grow in alkaline media, it is probable that those solutions which are alkaline will prove most efficient, other conditions being alike.

Besides the general experiments of the many who have treated wood with various chemicals, there is an extensive test which has given very definite results as regards *Lenzites sepiaria* and the decay caused by it. In 1902 (Von Schrenk, 1904) a piece of track was laid with experimental ties, both treated and untreated, in eastern Texas. The following coniferous timbers were used: Tamarack (*Larix laricina*) and hemlock (*Tsuga canadensis*) from Wisconsin; longleaf (*Pinus palustris*), loblolly (*P. taeda*), and shortleaf (*P. echinata*) pine from Texas. Eighteen months after the ties were placed in the track the writer assisted in the examination of them. The results are noted herein only for the coniferous species of wood and in connection with *Lenzites sepiaria*.

The untreated hemlock ties were seriously rotted, 90 out of 101 having sporophores of *Lenzites sepiaria* and of *Polystictus veriscolor* Fr. The former was present on most of the hemlock ties which bore fruiting bodies. The untreated shortleaf pine had 31 out of 100 which showed *Lenzites sepiaria*. The untreated longleaf pine had 68 out of 93 affected, some being badly rotted. The untreated loblolly had 57 out of 100 bearing fruiting bodies of this fungus. Of the untreated tamarack 37 out of 49 bore sporophores of *Lenzites sepiaria*. Of the methods of treatment tested the Wellhouse, zinc chlorid, and Allardyce processes gave satisfactory protection. The Barschall process did not give good results; treatment with spirittine gave fair results, and so far as *Lenzites sepiaria* is concerned, was satisfactory;

treatment with Beaumont oil was hardly satisfactory, 4 out of 42 loblolly ties having sporophores of *Lenzites sepiaria.* A detailed statement of these results is given by Von Schrenk (1904). The experiment shows that creosote, zinc tannin, zinc creosote, and zinc chlorid are efficient in the order named. The Barschall process, in which a mixture of copper, iron, and aluminum compounds is used, was not satisfactory. The Beaumont oil and spirittine were hardly satisfactory, but were applied in open vats without pressure.

In 1909 further examination of these ties was made (Faulkner, 1910; Winslow, 1910). No detailed statement is given as to the fungi which caused decay, so only the general results are of significance in the present paper; but the result with the best treatments, Allardyce, zinc chlorid, and Wellhouse, are of interest. It was found that a large number of the hemlock and tamarack ties which were treated by these methods are still in service. The following table gives the results:

Percentage of treated ties in service after 7½ years.

Kind of timber.	Method of chemical treatment.		
	Allardyce.	Zinc chlorid.	Wellhouse.
Hemlock	62	69	87
Tamarack	84	98	97

The untreated ties of hemlock averaged 1½ years of service, while the tamarack averaged 2½ years. This increase in service, due to treatment by the methods stated, based upon the service of untreated ties, was 430 per cent for loblolly ties, 370 per cent for hemlock, 280 per cent for tamarack, and 210 per cent for longleaf pine.

Besides the above methods of handling the timber itself, the collection and burning of decayed timber is of importance in reducing the attacks of this fungus. The custom of promptly burning the rotten ties by the American railroads is based on good judgment, and must have an appreciable effect upon the prevalence of wood-rotting fungi upon the ties in their tracks.

SUMMARY.

Practically three-fourths of the timber production of the entire country is furnished by the coniferous species of trees. The wood-rotting fungi are important factors in determining the length of service of this immense quantity of timber, *Lenzites sepiaria* being one of the most important of the fungi which attack coniferous species of wood. With several other species it destroys a large proportion of the coniferous railroad ties and telegraph and telephone poles which are in

service in the country. It alone probably destroys nearly one-fourth of these timbers. The latest statistics show that coniferous ties and poles bought in 1908 cost $32,500,000, making an annual item of more than $8,000,000 worth of timber which has its length of service seriously shortened by this fungus.

Lenzites sepiaria is widely distributed, being prevalent throughout Europe, in Australia, in the East Indies, and in South America. In North America it is undoubtedly present throughout Canada to the northern tree line, everywhere in the United States, and at least in the coniferous forests of Mexico. It occurs on the wood of Populus, Salix, Alnus, Abies, Larix, Picea, Pinus, Tsuga, Pseudotsuga, and Juniperus. It is a saprophyte, but under certain conditions can attack wood that is apparently alive. It usually enters timbers through season cracks and under favorable conditions is able to form mature sporophores within five months' time on newly cut timber. The fungus has been known in Europe for many years, being easily traced back to 1786. The sporophores are rather small, usually occurring in groups or fusing laterally. They may revive after long periods of desiccation, the writer having obtained spores from specimens after two years. The spores are given off by hundreds of millions. Hence, decayed timbers should be destroyed, as they are a prolific source of infection for new timber. Mature sporophores may be produced within 6 to 10 days after the first mycelium shows on the exterior of an affected timber. Many pure cultures have been made by the writer, usually using the living mycelium instead of spores for inoculation. Inoculations into green timber produced sporophores within five months' time in Texas.

The decayed wood is brown in color, irregularly fissured into tiny cubical masses which crumble into dust between the fingers.

Microchemical tests show that the lignin has lost some of its constituents and is disorganized. Pure cultures grown upon sterilized green wood have produced the decay which constantly accompanies the fruiting bodies in the field and forest.

The factors governing the growth of wood-rotting fungi are food, air, water, and temperature. These fungi cause decay by disorganizing the wood tissues in which their mycelium vegetates, and the above factors which govern their growth consequently govern the decay caused by them. Hence, the decay caused by *Lenzites sepiaria* may be prevented or greatly retarded (1) by seasoning, which decreases the water content of the timber to such a point that fungi can not readily grow; (2) by floating, which excludes the air and probably has some effect on the food materials within the timber; and (3) by chemical treatment, which infiltrates the wood with substances deleterious to the fungi.

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PLATES.

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DESCRIPTION OF PLATES.

PLATE I. Fig. 1.—End of longleaf pine log with many sporophores of *Lenzites sepiaria.* The small white masses on the left are sporophores of another wood-rotting fungus. Note the season cracks in the wood. Fig. 2.—Several new sporophores of *Lenzites sepiaria* showing their hymenial surface.

II. Fig. 1.—New railroad tie with early stage of decay caused by *Lenzites sepiaria.* The largest rotted area is located at a season crack in the upper surface of the tie. Fig. 2.—New railroad tie with medium stage of decay caused by *Lenzites sepiaria.* The rotted areas are located at season cracks.

III. Fig. 1.—Late stage of decay caused by *Lenzites sepiaria* in a longleaf pine tie which has been cut but a few months and never has been placed in service. Fig. 2.—Plug used in inoculating green timber. Removed in less than five months. A sporophore was formed on the outer end. Fig. 3.—Loblolly pine timber with *Lenzites sepiaria* sporophores in the season cracks.

IV. Longleaf pine block upon which a pure culture of *Lenzites sepiaria* has grown for about six months. This type of rot is the one which accompanies the fruiting bodies of this fungus so universally.

FIG. 1.—SPOROPHORES OF LENZITES SEPIARIA ON THE END OF A LONGLEAF PINE LOG.

FIG. 2.—SPOROPHORES OF LENZITES SEPIARIA, SHOWING UNDER SURFACE.

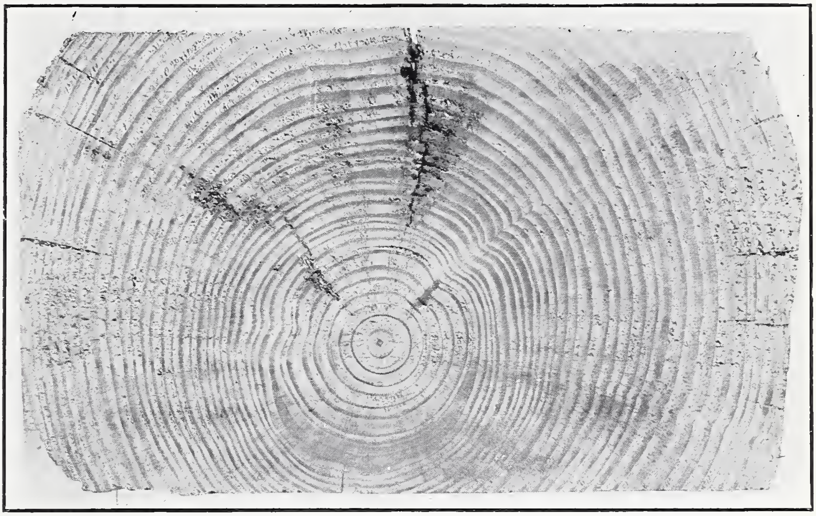

FIG. 1.—EARLY STAGE OF DECAY CAUSED BY LENZITES SEPIARIA.

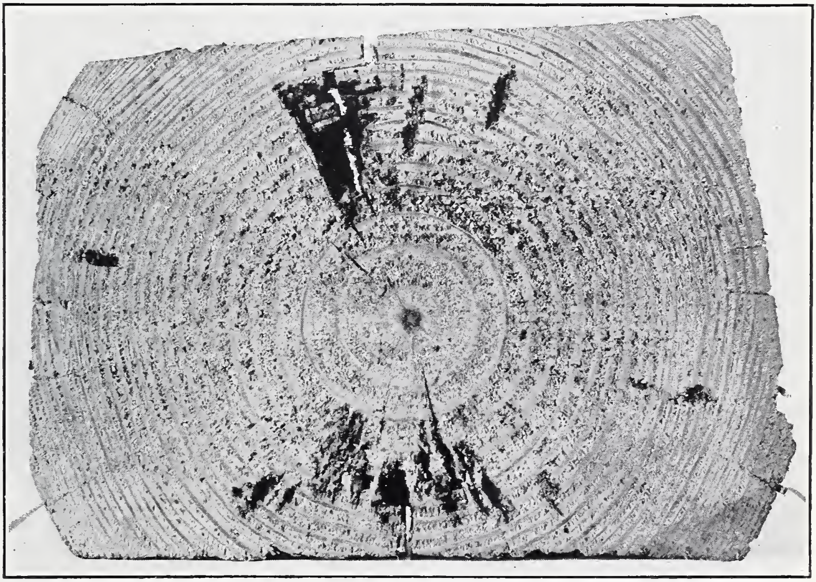

FIG. 2.—MEDIUM STAGE OF DECAY CAUSED BY LENZITES SEPIARIA.

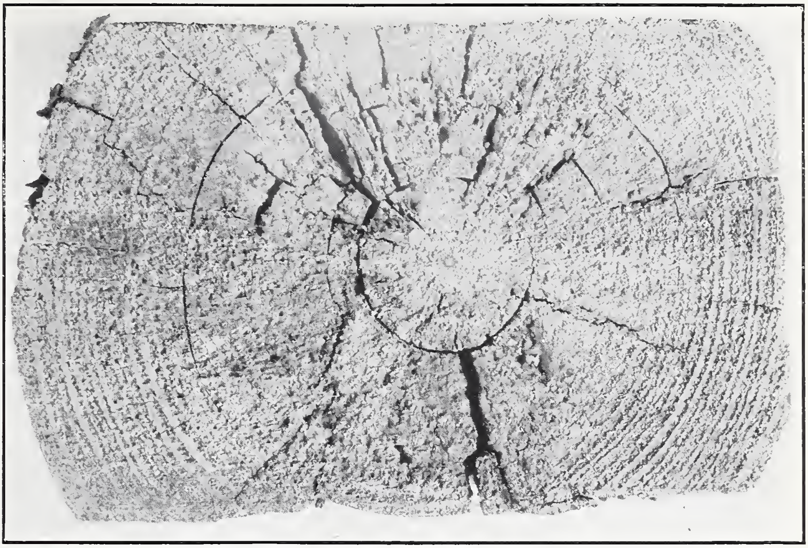

FIG. 1.—LATE STAGE OF DECAY CAUSED BY LENZITES SEPIARIA.

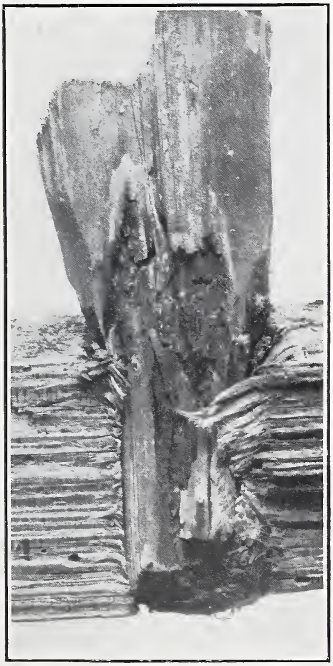

FIG. 2.—PLUG USED IN INOCULATION.

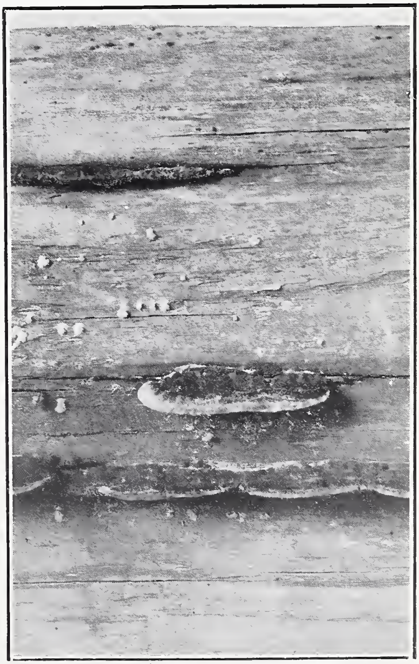

FIG. 3.—SPOROPHORES OF LENZITES SEPIARIA IN SEASON CRACKS.

PURE CULTURE OF LENZITES SEPIARIA ON LONGLEAF PINE BLOCK.

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